Detecting Stored-Product Moths in a Peanut Warehouse By Using Light Traps and Larval Traps

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Detecting Stored-Product Moths in a Peanut Warehouse By Using Light Traps and Larval Traps

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SUMMARY

Tests were conducted in a peanut warehouse to compare the effectiveness of green and ultraviolet lights in attracting stored-product insects to light traps. Ultraviolet and green lights appeared to be. equal in attracting Indian-meal moths, *Plodia interpunctella* (Hübner). However, about twice as many almond moths, *Cadra cautella* (Walker), and rice moths, *Corcyra cephalonica* (Staint.), were attracted to the green as to the ultraviolet light.

Insect larvae were captured in traps that were placed to take advantage of the insects' tendency to migrate to the highest part or the peaks of inshell stored peanuts. Electronic barriers were used in these traps to retain the captured larvae. Nearly all the larvae captured were of the almond moth. Of these, about three-fourths were females.

No stored-product beetles were captured in the light or the larval traps.

Numbers of insects flying on a particular day were influenced more by weather conditions that occurred before than on that day. High temperatures 10 to 14 days before trapping were associated with larger numbers of trapped Indian-meal moths, whereas lower temperatures 10 to 14 days before trapping were associated with larger numbers of trapped rice moths.

Radiographic analyses of the farmers' stock peanuts, as they arrived at the warehouse, revealed that insect larvae had been feeding on approximately nine of every 1,000 kernels. After 2 months' storage, about 20 percent of the surface peanut kernels showed feeding damage.

Under conditions of the test, both the light and larval traps were ineffective in controlling insect infestation. These traps, however, are valuable in detecting and monitoring insect infestations. In the test, green light traps, rather than ultraviolet light traps, were more satisfactory for this purpose.

BACKGROUND AND OBJECTIVES

Many types of insect traps are now available. They have been used for over 100 years. Entomologists use light traps to build up their collections or to study insect populations and migrations. Some traps are used as survey tools, whereas others are used to control insects (*2*).[2] In tobacco warehouses the presence of the cigarette beetle, *Lasioderma serricorne* (Fabricius), is often detected by use of ultraviolet light traps (*12*). Stermer (*9*) and Soderstrom (*8*) found that certain stored-product insects were attracted to green light. In laboratory and simulated warehouse studies, Kirkpatrick, Yancey, and Marzke (*6*) showed that moths were generally more attracted to green light and that beetles were more attracted to ultraviolet light. They further

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[2] Italic numbers in parentheses refer to Literature Cited, p. 18.

showed that this preference for green or ultraviolet light exhibited by these insects was greater than for a combination of the two lights. Other researchers (*3, 4*) have used ultraviolet light to estimate field-insect populations.

In surveys conducted between 1955 and 1959, hundreds of truckloads of peanuts arriving at warehouses in Georgia were found to be infested with insects that cause the most damage in storage (*11*). The level of infestation was low, but sufficient to cause damage during storage.

Insect damage to growing peanuts usually is evident, but early insect damage to harvested peanuts is not readily detected. The peanut insect injury and infestation begin in the field during harvesting and build up with time at ordinary temperatures (*14*). After peanuts are harvested, insects continue to be a serious problem if the peanuts are stored at temperatures above 48° F. (*10*).

Insect traps can be used for detecting insect larvae and adults, but they cannot detect infestation hidden within the peanut kernels.

Radiographic techniques, therefore, have been modified to detect internal infestations in farmers' stock peanuts. These techniques were used during the test period to determine the amount of internal feeding damage (*5*). Pupae and the various stages of larvae can be detected in unshelled peanut kernels when X-ray techniques are used.

After the larvae complete their feeding, they migrate to the peaks of the long peanut stacks where they pupate and change into adult moths. Larval traps are placed here to take advantage of a larva's tendency to migrate to higher surfaces.

This report describes tests conducted to provide additional data needed on initial insect infestation of farmers' stock peanuts during storage. The tests were conducted, therefore, to determine:

- If light is effective in attracting stored-product insects to insect traps.
- If stored-product insects are attracted to ultraviolet light or to green light.
- If the numbers of adult insects or larvae attracted to the traps are related to temperature, humidity, or vapor-pressure deficit, or all three, occurring inside the warehouses.
- If larval traps are effective for monitoring the amount of larval infestation in stored peanuts.
- If light or larval traps are effective in controlling insect infestation in stored farmers' stock peanuts.

MATERIALS AND METHODS

Sampling Areas

Tests were conducted from October 11 to December 19, 1965, in two peanut warehouses located in Georgia. Warehouse No. 1 was 350 feet long, 300 feet wide, and 15 feet high. It was divided into three separate areas, A, B, and C, to store bulk peanuts (fig. 1). The size of area A was 140 by 50 feet. Area B, located on the opposite side of the warehouse, measured approximately 110 by 90 feet. Both areas A and B were filled with peanuts to a depth of approximately 10 feet. Area C, located adjacent to area B, was oval. It was approximately 45 by 18 feet and was filled with peanuts to an average depth of 6 feet. Warehouse No. 2, area D, was an elevator-type structure composed of five metal bins, three of which were used in the test. The base of each bin was 150 feet long and 50 feet wide. The apex of each bin was 12 feet wide and contained loading equipment used to move incoming peanuts. Each of the three bins was filled with peanuts to a depth of 30 feet.

Equipment

Green Light Traps

The green light source was a Sylvania Tape Lite panelescent lamp that was rated at 120 volts and 60 cycles a.c. The lamp used 0.3 watt per foot (Code T–10603) and emitted 2.5 footlamberts. In tests using this light, two 24-inch strips of Tape Lite were taped to the intake funnel of a suction light trap. This trap consisted of an intake funnel and hood, a 12-inch-diameter throat that contained a fan, a screen to allow the air to escape, and a 1-quart plastic jar to hold captured insects (fig. 2 A).

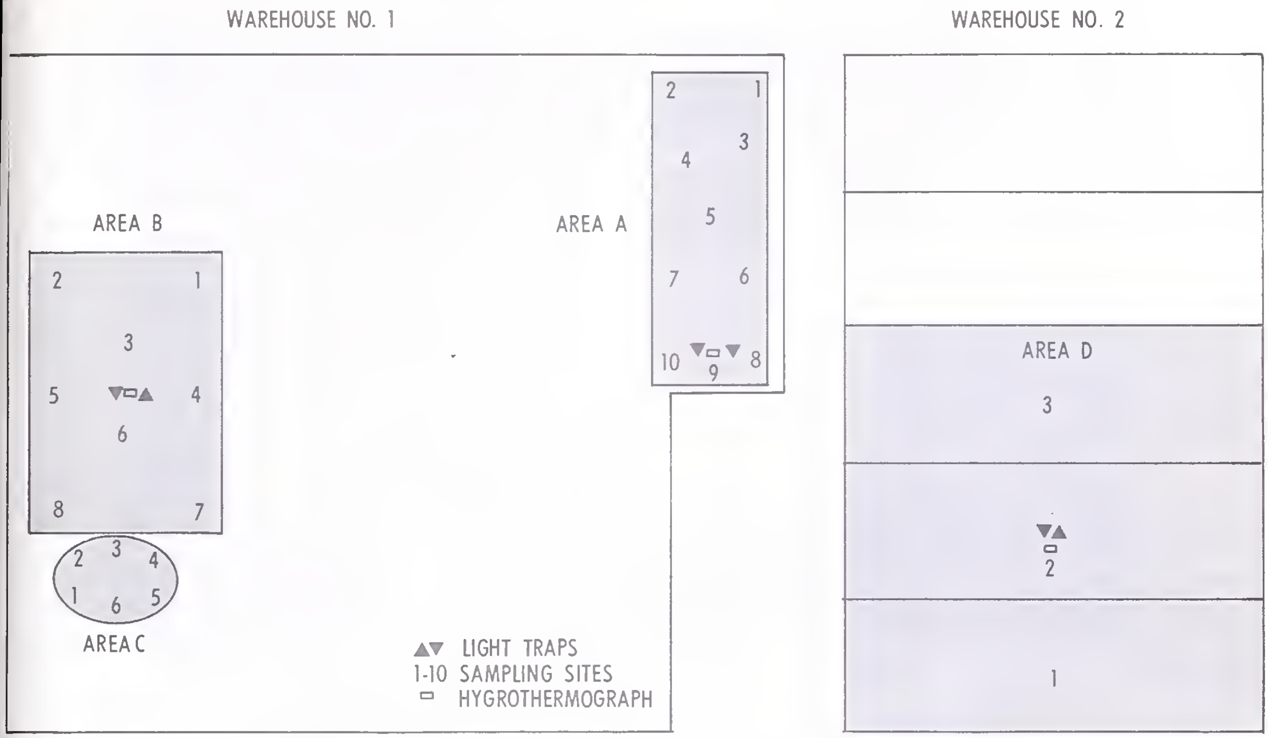

FIGURE 1.—Sampling sites and equipment placed in sampling areas.

Ultraviolet Light Traps

The ultraviolet light source was a General Electric 32-watt circline F-C 12T10/BL rapid-start ultraviolet lamp. This lamp emitted 100 foot-lamberts between 3,200 and 4,000 angstroms. The lamp was mounted in the intake funnel of a suction light trap of the same type as that used with green light traps.

Plastic jars were used in both green and ultraviolet light traps throughout the experiment to retain captured insects. Plastic jars were used as a safety measure because glass, if broken, would be difficult to remove from the peanuts, during the cleaning, shelling, or manufacturing processes.

Larval Traps

Larval traps consisted of inverted No. 10 (165-ounce) Lily tubs with bottomless 6-ounce hot drink cups inserted in the upper end (fig. 2 B). Electrical metallic barriers placed inside the cup and kept in position with nonmetallic tape were used for retaining captured larvae. Each barrier consisted of two aluminum foil strips that were separated 1/16 inch apart. Two 18-inch pieces of No. 22 gage wire, with 6 inches of insulation removed, were inserted through the cup and fastened to the aluminum foil strips, one to the upper part and the other to the lower part. A battery terminal clip was soldered to the two wires and was attached to a No. 415, 45-volt radio battery placed inside the inverted tub.

Laboratory and field trials were made to test the effectiveness of the traps in preventing the captured insects from escaping. In the trials, larvae were observed crawling up the cardboard trap and onto the positive section of the aluminum foil. A larva would not detect the electrical current until part of its body crossed the 1/16-inch opening, thereby completing the electrical circuit with its body. The larva would immediately contract its body, release its hold on the aluminum foil, and drop to the bottom of the trap. When the larva tried to leave the container, these events were repeated and it would again drop to the bottom of the trap.

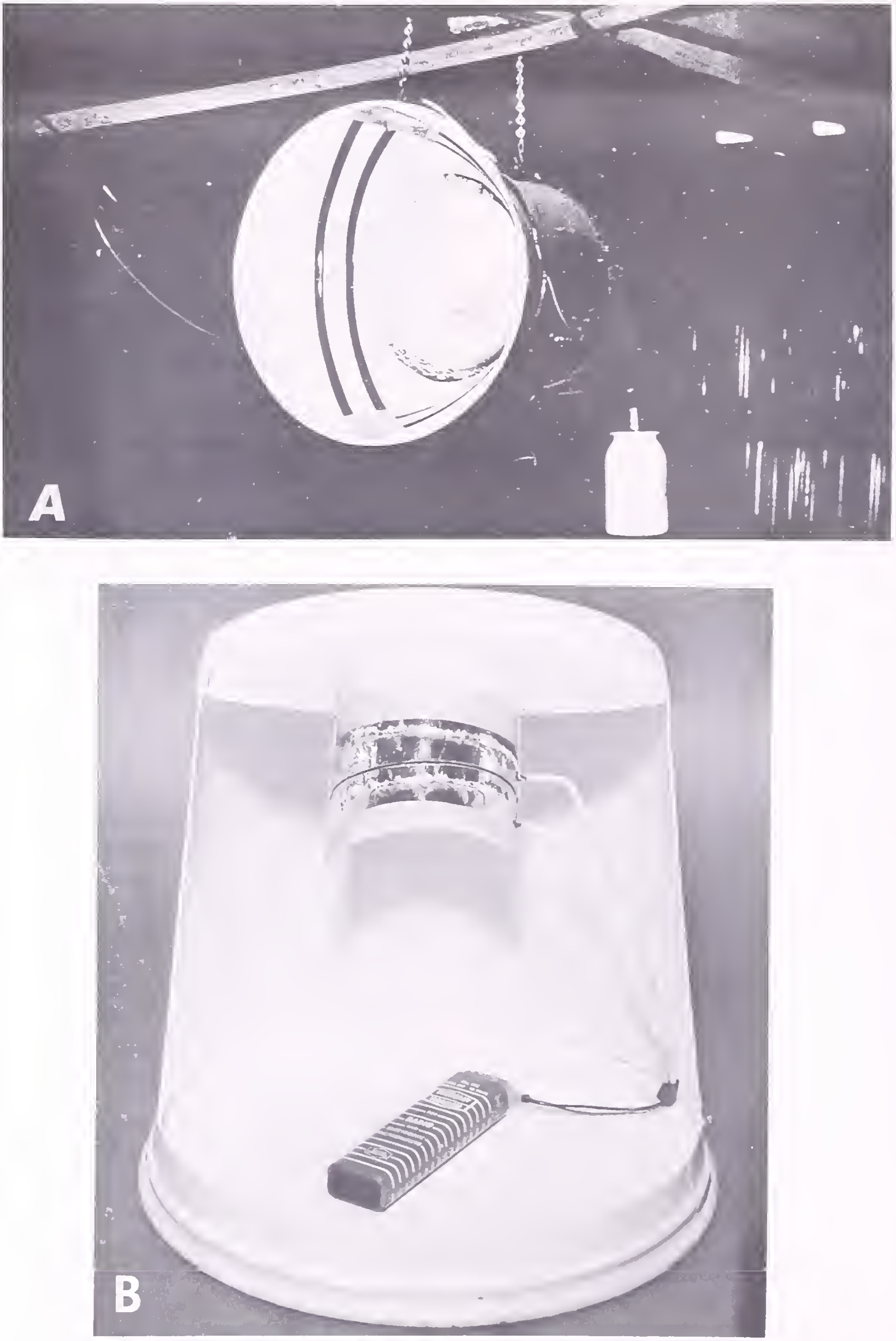

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FIGURE 2.—Light trap (A) and cutaway of larval trap (B) used to capture the insects found in peanut warehouses.

Hygrothermographs

These instruments recorded changes in both temperature and relative humidity on a single dual-channel chart. Air temperature was sensed by a bimetal assembly that expanded or contracted with temperature changes. Humidity was sensed by the expansion or contraction of a human-hair element. Readings were accurate to within 4 percent.

Placement of Equipment in Sampling Areas

Approximately 8 weeks after the farmers' stock peanuts began arriving at the warehouses, stored-product insect moths were observed flying near the peanuts, and larvae could be seen crawling on the stored peanuts. At this time, both light and larval traps were installed in the locations shown in figure 1.

Tests with green and ultraviolet lights were conducted in areas A, B, and D (fig. 1). Green and ultraviolet light traps were placed 12 feet apart at one end of area A. They were supported 4 feet above the level of the stored peanuts. Both traps faced toward the opposite end of area A. Green and ultraviolet light traps, facing opposite directions, were placed 24 inches apart in the center of area B and were mounted 4 feet above the level of the stored peanuts (fig. 2 A). In area D, these traps were mounted 12 inches apart and 6 feet above the level of the peanuts. They also faced opposite directions.

One week after the light traps were installed, larval traps (fig. 2 B) were placed on the peaks of the unleveled stored peanuts at the sampling sites in areas A and C. Area A had 10 sampling sites and area C, six (fig. 1).

Hygrothermographs were placed on the surface of the peanuts below the light traps in areas A and B (fig. 2) to monitor ambient temperature and relative humidity throughout the test. In area D, a hygrothermograph was mounted at the same level as the light traps.

Handling of Peanuts

Farmers' inshell stock peanuts were tested for moisture content as they were brought to the warehouse. If their moisture content was 9 percent or less, they were moved directly into the storage areas. Peanuts above 9 percent were dried first in a mechanical dryer before placed in storage.

During the last week of each month of storage, malathion (1.75 pounds of 57-percent premium-grade malathion wettable powder in 2 gallons of water) was applied to the surface of the peanuts at a rate of 2 gallons per 1,000 square feet. During this surface treatment neither the light nor the larval traps were removed or disconnected. Although the larval traps were coated with the malathion solution, the insecticide did not affect the insects quickly enough to prevent their entering the traps.

Data Collection and Analysis

At the beginning of the study, random samples were taken from 44 lots of incoming peanuts for analysis by radiographic techniques for internal infestation and feeding damage. Later on, approximately 1 month after the light traps were installed, and at 2-week intervals until the peanuts were removed from the warehouse, one-quart samples were taken for radiographic analysis from the upper 1- to 2-inch levels of the stored peanuts, at different sampling sites. The samples were drawn from locations immediately adjacent to the larval traps in areas A and C. In addition, samples for radiographic analysis were taken from eight sampling sites in area B and three sampling sites in area D (fig. 1). The radiographs were made with a General Electric X-ray grain inspection unit (20 kilovolts and 5 milliamperes of power, 2.5-minute exposure, and type M industrial film).

The plastic jar from each light trap was replaced twice each week for 20 sampling periods. Beginning with sampling period 3, larval traps were emptied the same day that jars from light traps were replaced. Captured stored-product insects were identified, counted, and discarded. No insects were released to replace those captured.

Values of temperature and relative humidity for each hour were determined from the hygrothermograph charts and were recorded for analysis. Hourly readings of temperature and relative humidity were combined into a single

variable, vapor-pressure deficit (*VPD*), by the following formula:

$$VPD = (0.01) \quad [(100\text{-}RH) \quad \log^{-1} \quad (/9.07366 - 2294.739/TA)]$$

Where: TA = Absolute temperature = $5/9(TF-32) + 273.18$
TF = Temperature (° F.)
RH = Relative humidity (%)

This formula gave values within 1 percent of tabular values of vapor-pressure deficit (*7*) within the range of the data. Average values of temperature, relative humidity, and vapor-pressure deficit for each sampling period were calculated for all storage areas.

TABLE 1.—*Frequency of occurrence of different levels of internal insect damage in 44 lots of farmers' stock peanuts* [1]

Percentage of kernels damaged internally by larvae	No. of lots	Percentage of kernels containing larvae	No. of lots
0	1	0	13
0.01-0.50	11	0.01-0.25	16
0.51-1.00	18	0.26-0.50	12
1.01-1.50	10	0.51-0.75	3
Over 1.50	4	Over 0.75	0
Mean 0.85	44	Mean 0.20	44

[1] One sample was examined for each lot. Sizes of sample ranged from 300 to 815 peanuts.

RESULTS

Initial Insect Infestation

Insect-feeding damage was observed in all but one lot of incoming farmers' stock peanuts (table 1). Insect larvae had fed on approximately nine of each 1,000 kernels at the time of harvest, and approximately 0.2 percent of the sample peanuts contained larvae when they were X-rayed at the beginning of the study.

Environmental Conditions During Test

Temperatures for the sampling periods ranged from about 80° F. in mid-October to about 50° in December and relative humidities, from about 55 to 80 percent (table 2). Temperatures and relative humidities in area A averaged about the same as those in area B. Temperature in area D, however, usually averaged higher. The triangular elevator-type structure (warehouse No. 2, area D) apparently trapped and held heat for a longer period of time than the flat storage-type structure (warehouse No. 1, areas A and B). Vapor-pressure deficits in all three areas ranged from 2.6 to 13.3.

Insects Caught in Light Traps

During the study, 83,060 adult stored-product insects were captured in the light traps. Before malathion was approved as a surface treatment for peanuts, the Indian-meal moth, *Plodia interpunctella* (Hübner), was the most common insect found in peanut warehouses. During this study, Indian-meal moths represented only a small part of the insects captured in the light traps. The type of light had little influence on the number of Indian-meal moths captured. In the study, 180 adult Indian-meal moths were captured in the green light traps and 219 in the ultraviolet light traps. During the test period, most of these moths were trapped during the last week of October and the first week of November (table 3).

Although several species of beetles are often found infesting stored peanuts, none were captured in either the light or the larval traps.

The almond moth, *Cadra cautella* (Walker), will develop on a large number of commodities including grain and nut crops. It is commonly found in stores where seed is sold (*13*). During the study, 92 percent of all stored-product insects captured in light traps were almond moths. Twice as many almond moths were captured in the green light traps as in the ultraviolet light traps (50,230 compared with 25,896) (fig. 3). After the average temperature dropped on November 28, number of almond moths captured in light traps declined drastically.

The rice moth, *Corcyra cephalonica* (Staint.), is a large stored-product moth. Besides rice and other seeds it attacks cocoa, chocolate, and dried fruit. Although prevalent

TABLE 2.—*Average temperature, relative humidity, and vapor-pressure deficit in 3 peanut storage areas during each sampling period*

Sampling period	Last day of period	Temperature			Relative humidity			Vapor-pressure deficit		
		Area A	Area B	Area D	Area A	Area B	Area D	Area A	Area B	Area D
	Date	° *F.*	° *F.*	° *F.*	*Percent*	*Percent*	*Percent*			
1	Oct. 14	76.8	74.2	77.2	62.0	59.6	65.8	9.9	9.7	12.5
2	Oct. 17	81.1	79.9	81.1	66.0	64.5	64.7	10.2	10.3	13.3
3	Oct. 20	72.9	71.0	73.4	67.4	65.1	62.7	7.4	7.3	8.3
4	Oct. 24	73.8	72.4	75.5	68.9	67.8	66.3	7.7	7.7	11.9
5	Oct. 27	68.6	70.4	68.1	70.0	69.8	73.8	5.7	6.0	5.8
6	Oct. 31	68.7	69.4	72.6	62.4	62.8	62.4	8.3	8.3	13.3
7	Nov. 3	61.0	63.0	63.3	69.2	67.9	73.5	4.6	5.1	5.8
8	Nov. 7	62.4	62.6	68.3	60.6	60.7	59.9	6.9	6.9	12.2
9	Nov. 10	70.3	71.3	72.0	70.9	71.9	70.5	6.1	6.1	8.2
10	Nov. 14	67.6	68.8	68.9	68.8	70.0	69.9	5.7	5.7	7.3
11	Nov. 17	60.8	60.7	65.7	60.2	61.7	63.4	6.8	6.4	11.0
12	Nov. 21	62.8	64.6	65.9	58.2	59.0	58.9	6.9	7.1	10.0
13	Nov. 23	56.3	57.5	56.8	60.7	60.4	66.0	5.1	5.3	6.3
14	Nov. 28	60.8	62.1	64.7	61.3	60.4	63.3	6.2	6.5	9.4
15	Dec. 1	50.7	52.2	54.1	57.6	57.0	65.7	4.6	4.8	6.1
16	Dec. 5	53.1	53.1	53.8	55.0	56.6	65.9	5.1	4.9	5.8
17	Dec. 8	64.0	64.8	68.1	71.7	75.5	70.4	5.0	4.4	8.9
18	Dec. 12	62.2	63.5	62.8	77.1	80.9	80.2	3.7	3.2	4.4
19	Dec. 15	49.8	50.9	50.3	71.9	75.6	76.1	2.9	2.6	3.6
20	Dec. 19	51.1	52.3	50.5	69.2	75.4	73.8	3.4	2.9	4.2

in the Southern States, it is not well established in other areas of the country (*1*, *13*). During the test period, rice moths were first detected in late October. A significantly greater number of rice moths were captured in area A than in areas B or D. A total of 3,938 rice moths were captured in the green light traps and 2,597 in the ultraviolet traps.

Larval Infestation

Larvae Captured in Traps

More than 99 percent of the larvae captured were those of the almond moth. The only other larvae captured were those of the Indian-meal moth. No rice moth larvae were found in the larval traps. Of 12,219 larvae captured, only 59 were Indian-meal moth larvae. The average number of larvae captured per day in larval traps during each sampling period is shown in table 4. Of the total almond moth larvae captured, approximately 75 percent were females (fig. 4). No reason can be given for this deviation from the expected 1 to 1 ratio of females to males as found in the laboratory.

Larval activity appeared to be greater in the last part of November (area A, sampling periods 13 to 15) (table 4 and fig. 4). However, a rapid buildup of larvae appeared in area C, sampling site 1, during the seventh sampling period. To reduce the possibility of a high-insect infestation, approximately 1 ton of peanuts was removed from area C, sampling site 1. Larval traps were effective here in showing the time and place of a potentially heavy insect infestation as a high infestation occurred later in sampling site 6 adjacent to site 1 (fig. 5).

Numbers of trapped larvae revealed relatively high infestations of insects at each end of storage area A, sampling sites 2 and 9, and low infestations within the central part of the area (fig. 5 and table 5). Storage area C also had contrasting areas of low- and high-insect infestation.

Larvae Detected by Radiographs

Radiographs (fig. 6) were made from peanut samples taken at the surface at 2-week intervals, beginning with the eighth sampling period

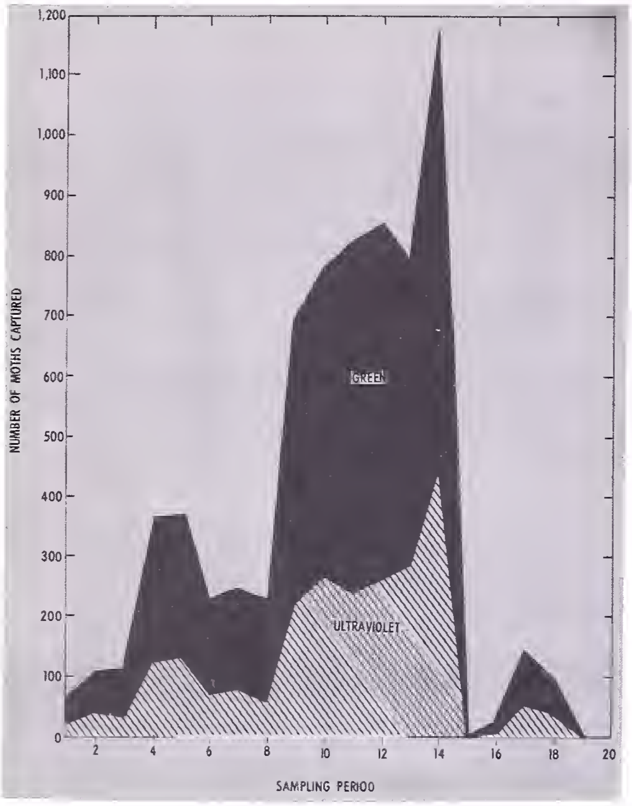

FIGURE 3.—Average number per trap per day of adult almond moths attracted to green and ultraviolet light traps.

(November 3-7). The percentage of peanut kernels containing hidden insect-feeding damage is shown in table 5.

Larval infestations and amounts of feeding damage were generally greater in areas A and B than in areas C and D. All four storage areas showed an increase in the hidden insect damage as the storage time increased (fig. 7).

Only a weak relationship existed between numbers of larvae caught in the larval traps compared with the average percentage of larvae and pupae found in the radiographs of surface samples of farmers' stock peanuts from the different storage areas (table 4 and fig. 7). Apparently, the larvae moved about from site to site in the storage areas. Not enough storage areas were included in this study to establish the degree of reliability with which numbers of larvae trapped can be used for predicting insect damage to peanuts.

Effect of Temperature, Relative Humidity, and Vapor-Pressure Deficit Upon Insect Activity

Insect activity was surmised to be affected by prevailing weather conditions. Insects flying on any particular day could have been influenced more by weather conditions before their capture than by ambient weather conditions.

Simple correlation analyses were made to determine whether the number of insects attracted to traps was related to temperature, relative humidity, or vapor-pressure deficit occurring during the trapping period or some time before the trapping period.

To facilitate data analysis, any period of interest was defined as period *J*. The sampling period preceding *J* was called period *J*-1; the period before *J*-1 was designated *J*-2, and so on. For example, when sampling period 4 (October 20 to 24, table 2) was considered period *J*, sampling period 3 was *J*-1 (October 17 to 20). Insect counts used in correlations were those obtained in period *J*. The physical variables (weather) were averaged for each of the 20 sampling periods. The insect counts

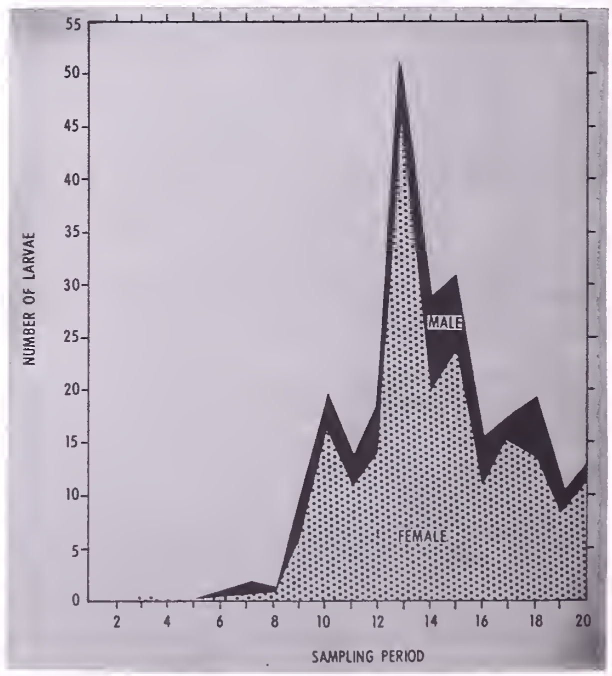

FIGURE 4.—Average number of almond moth larvae captured per day in storage area A.

TABLE 3.—*Average numbers of stored-product insects captured in green and ultraviolet light traps during each sampling period* [1]

Sampling period	Last day of period	Indian-meal moth		Almond moth		Rice moth	
		Ultraviolet	Green	Ultraviolet	Green	Ultraviolet	Green
	Date	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
1	Oct. 14	1.7	0.8	28.2	40.2	0	0
2	Oct. 17	2.9	2.6	41.3	61.8	0	0
3	Oct. 20	.6	1.3	38.0	70.2	0	0
4	Oct. 24	1.0	4.1	117.8	247.0	0	0
5	Oct. 27	3.1	1.5	132.5	238.1	3.8	.2
6	Oct. 31	2.3	3.6	74.1	150.3	1.9	1.1
7	Nov. 3	3.1	4.1	78.9	165.9	7.7	10.0
8	Nov. 7	2.8	1.9	61.3	167.2	5.0	10.8
9	Nov. 10	0	.3	225.4	470.2	2.3	3.0
10	Nov. 14	1.2	.3	261.8	522.2	3.5	8.9
11	Nov. 17	0	.6	240.8	585.2	3.3	8.7
12	Nov. 21	.2	.2	270.3	584.7	3.5	4.5
13	Nov. 23	.5	.2	284.2	495.0	6.7	15.0
14	Nov. 28	0	0	447.3	730.0	19.1	29.3
15	Dec. 1	0	0	4.6	1.2	41.8	52.8
16	Dec. 5	0	0	7.0	11.4	39.1	53.5
17	Dec. 8	0	0	54.4	85.8	23.7	35.4
18	Dec. 12	0	0	36.4	61.6	49.6	90.2
19	Dec. 15	0	0	1.3	0	7.6	9.0
20	Dec. 19	0	0	1.4	2.6	19.2	26.1
Average	-------	1.0	1.1	120.3	235.0	11.9	17.9

[1] Average number per trap per day in areas A, B, and D.

were correlated with the physical variables for period *J* and for the five sampling periods that preceded period *J*.

Results of the correlations analyses are given in tables 6, 7, and 8. Separate correlation analyses were made for each location. Combinations of insect counts and physical variables producing significant correlations in at least two of the three locations are italicized in tables 6 to 8 to distinguish them from other combinations. Isolated "significant" correlation coefficients would be expected in analysis of this type because of chance alone. However, when the same combinations were found to be significantly correlated in two or three different locations, the relationships were believed to be real.

Insect Counts Versus Average Temperature

Numbers of almond moths trapped between October 11 and December 19 appeared to be unrelated to temperatures occurring any time within the 21-day period before trapping (table 6). Indian-meal moths and rice moths were affected by temperatures but in different ways. Numbers of Indian-meal moths caught in ultraviolet light traps were significantly correlated with average temperatures 10 to 14, 14 to 17, and 17 to 21 days before trapping (table 6). High temperatures during this time were associated with high-insect counts. Numbers of Indian-meal moths caught in green light traps were correlated with average temperatures 7 to 10, 10 to 14, 14 to 17, and 17 to 21 days before trapping. These results indicate that Indian-meal moth *adult* activity is affected by temperatures that occur during the larval stage. The critical time appears to be between 7 and 21 days.

Counts of rice moths appeared to be influenced by average temperatures occurring during the 10 days before trapping. Temperatures occurring more than 10 days before trapping appeared to have less effect upon the numbers captured. Rice moths attracted to

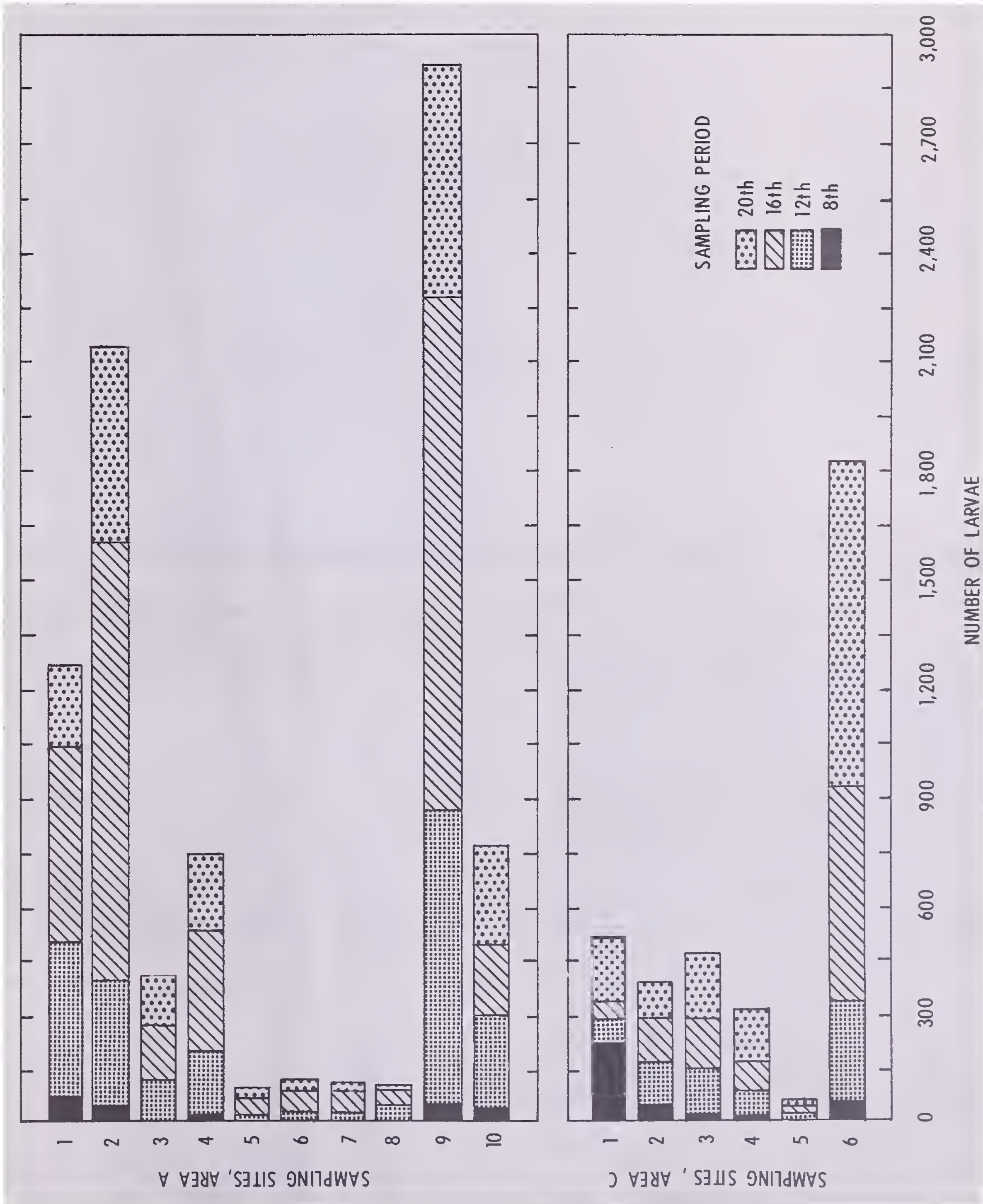

FIGURE 5.—Cumulative numbers of almond moth larvae captured in traps at each sampling site in storage areas A and C at sampling periods 8, 12, 16, and 20.

TABLE 4.—*Numbers of larvae of Indian-meal moth and almond moth captured in larval traps in storage areas A and C*

Sampling period	Last day of period	Larvae in area A Total	Larvae in area A Average per day	Larvae in area C Total	Larvae in area C Average per day
	Date	*No.*	*No.*	*No.*	*No.*
3	Oct. 20	24	8	---	---
4	Oct. 24	6	2	10	3
5	Oct. 27	15	5	36	12
6	Oct. 31	57	14	52	13
7	Nov. 3	65	22	223	74
8	Nov. 7	51	13	35	9
9	Nov. 10	293	98	179	60
10	Nov. 14	805	201	280	70
11	Nov. 17	417	139	69	23
12	Nov. 21	787	197	161	40
13	Nov. 23	1,017	509	100	50
14	Nov. 28	1,443	289	419	84
15	Dec. 1	940	314	196	65
16	Dec. 5	617	154	270	68
17	Dec. 8	525	175	419	156
18	Dec. 12	766	192	538	135
19	Dec. 15	302	101	127	42
20	Dec. 19	526	132	449	112

ultraviolet light were responsive to temperature in the same way as those attracted to green light except with a longer period of influence of temperatures before trapping (table 6). However, the response of the rice moth to temperature was opposite to that of the Indian-meal moth. Whereas, Indian-meal moth activity was greater when *higher* temperatures occurred during the critical periods, rice moth activity was greater when *lower* temperatures occurred (table 6; note algebraic signs of correlation coefficients).

Insect Counts Versus Average Relative Humidity

Numbers of almond moths caught in both ultraviolet and green light traps were associated with relative humidities 14 to 17 days before trapping. Numbers of almond moths caught in ultraviolet light traps were also associated with relative humidities 17 to 21 days before trapping (table 7). Relative humidity appeared to have little effect upon numbers of Indian-meal and rice moths captured.

Insect Counts Versus Average Vapor-Pressure Deficit

Numbers of almond moths captured in light traps were not associated with vapor-pressure deficits occurring during or before the trapping period. In contrast, counts of Indian-meal moths were associated with vapor-pressure deficits occurring at several different time intervals before trapping, while the rice moth's significant values occurred in the 0- to 3-day period (table 8). Although the correlations were seldom significant, counts of rice moths showed a trend towards an inverse relationship with vapor-pressure deficits (table 8; note negative algebraic signs of correlation coefficients).

DISCUSSION

Light and larval traps are valuable for detecting stored-product insects and for indicating when additional control measures are necessary. Greater numbers of stored-product moths that infest stored peanuts were attracted to green light than to ultraviolet light.

During previous studies of laboratory cultures, male and female larvae were approximately equal in numbers. However, in this study larval trap ratios were three females to one male. This ratio could not be compared with that for the adults collected in light traps in this study because so many adults were trapped that they were not sexed.

The inexpensive larval traps used in this study were effective in capturing and retaining the larvae. The electrical metallic barrier that was used has many advantages; it is constructed of inexpensive materials that are easily removed, and it contains no toxic materials as are needed in the insecticidal larval traps.

Radiographs revealed larval forms, insect-feeding damage to kernels, and pupal stages of the moths inside the stems or unshelled kernels. Radiograph data can be used to determine whether control measures are successful.

The light and larval traps were valuable in detecting but not in controlling infestation.

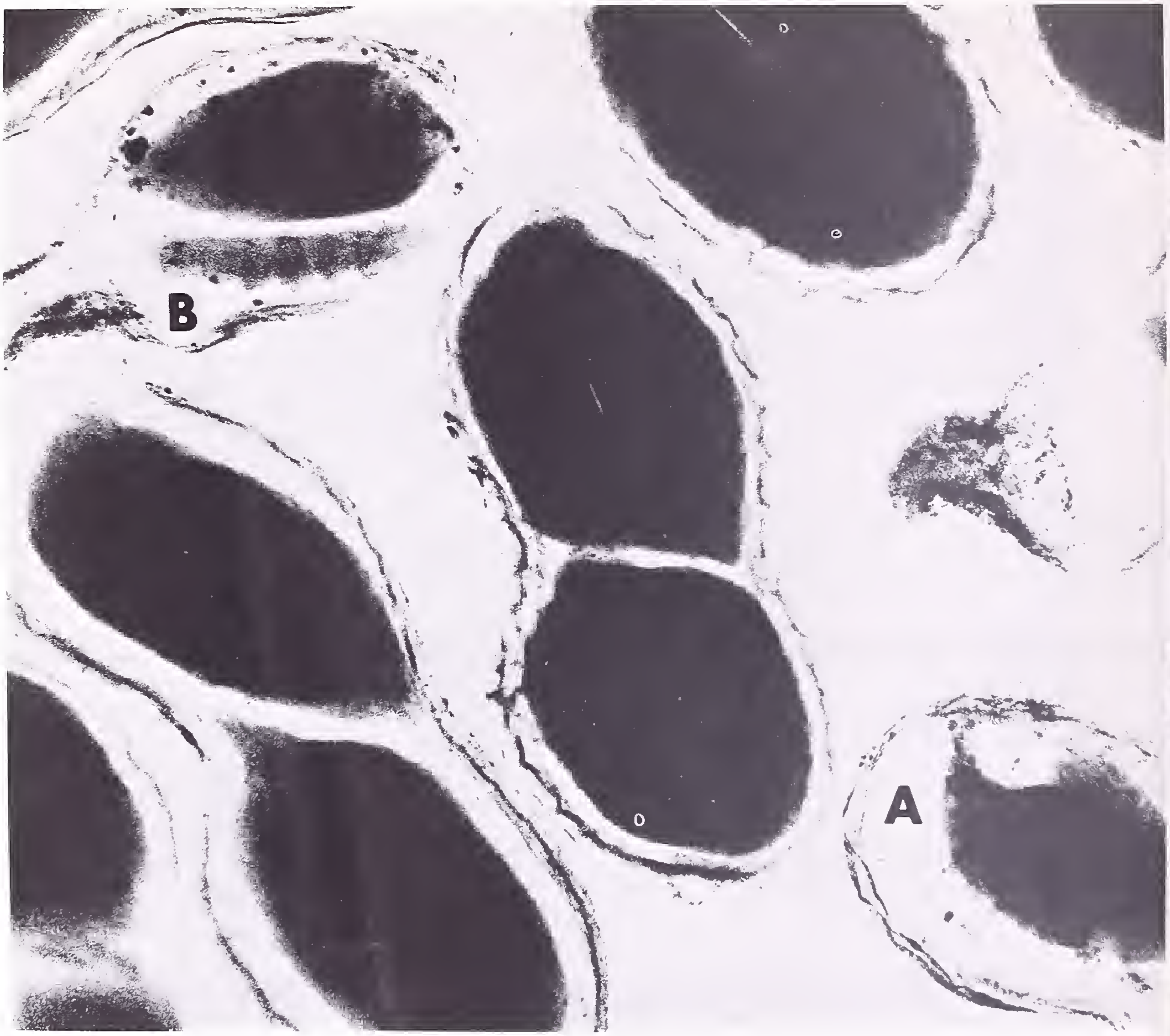

FIGURE 6.—Radiograph of peanuts showing (A) insect-feeding damage and (B) larva in peanuts.

Surface-feeding damage occurred in over 35 percent of the peanuts at one sampling site and averaged over 20 percent for all sampling sites (table 5).

Each of the three physical variables, temperature, relative humidity, and vapor-pressure deficit, showed different correlation patterns with insect counts. Temperature appeared to have the most influence upon the number of flying insects, and relative humidity, the least. Vapor-pressure deficit, as measured by total number of significant correlations in tables 6, 7, and 8, was intermediate between that of temperature and relative humidity. However, several counts were significantly correlated with temperature and relative humidity but not with vapor-pressure deficit. Correlations were not significant in some periods between either temperature and insect counts or relative humidity and insect counts but were significant between vapor-pressure deficits and insect counts.

For more efficient control of stored-product insects in peanut warehouses, the operator needs additional information to determine: (1) Whether male larvae pupate near their feeding site within shells and hollow stems and females migrate to different locations; (2) whether the numbers of larvae captured in the larval traps could forecast the future adult population; (3) whether temperature, relative humidity, and vapor-pressure deficit could be used to forecast developing infestations; (4) whether the adult rice moth is usually more active at lower temperatures than either the almond or Indian-meal moth; and (5) whether the distance the stored-product insects travel can be detected by the light or larval traps.

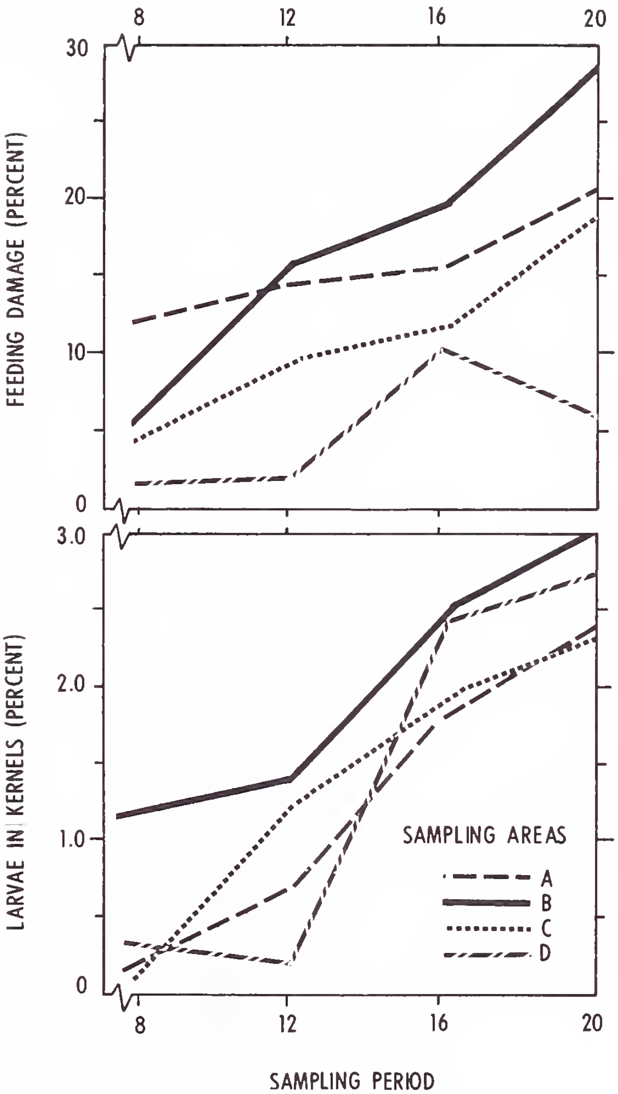

FIGURE 7.—Percentages of kernels containing larvae and kernels with internal feeding damage as found by radiographic analysis. (Peanuts were removed from area D sampling sites 2 and 3 during sampling periods 16 and 20.)

TABLE 5.—*Feeding damage shown on radiographs, and numbers of larvae captured at each sampling site in storage areas A and C* [1]

Storage area and sampling site	November 7		November 21		December 5		December 19	
	Feeding damage	Larvae [2]	Feeding damage	Larvae [2]	Feeding damage	Larvae [2]	Feeding damage	Larvae [2]
	Percent	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*
A								
1	5.5	69	7.2	495	11.8	1,033	20.4	1,271
2	8.4	29	7.2	399	6.8	1,622	16.7	2,136
3	17.3	6	14.7	115	16.9	272	22.6	418
4	14.1	15	18.7	207	21.4	539	28.6	746
5	1.4	1	2.6	24	3.7	59	3.8	82
6	7.5	6	8.4	25	10.5	75	11.5	112
7	12.3	1	9.8	27	18.8	81	15.6	110
8	21.1	8	20.3	47	22.7	82	22.4	102
9	26.3	47	36.4	875	29.0	2,275	35.2	2,917
10	7.3	35	17.5	305	12.6	499	28.4	762
C								
1	5.6	229	8.0	294	9.3	346	14.3	512
2	6.3	40	9.5	173	8.3	277	4.7	394
3	3.7	19	9.7	147	12.2	285	11.0	473
4	4.9	12	6.4	79	14.1	170	18.5	322
5	3.2	3	13.9	14	14.2	20	32.6	42
6	1.8	53	8.7	338	11.7	932	34.3	1,820

[1] Correlation coefficients for percent feeding damage vs. number of larvae captured were —0.14 for November 7, 0.56 for November 21, 0.28 for December 5, and 0.49 for December 19. Critical value at the 5 percent level is 0.497.

[2] Total number of larvae captured up to and including the day of sampling for radiographic analysis.

TABLE 6—*Correlation coefficients of numbers of adult insects captured in light traps in a sampling period compared with average temperatures during this period and during each of the 5 previous sampling periods* [1]

Sampling period, days before insects were trapped, and peanut-storage area	Ultraviolet light			Green light			Number of sampling period observations [2]
	Indian-meal moths	Almond moths	Rice moths	Indian-meal moths	Almond moths	Rice moths	
_J_							
0 to 3 days:							
A	0.61**	0.09	−0.30	0.33	0.07	−0.30	20
B	.20	.06	_−.58**_	.05	−.55*	_−.50*_	20
D	.33	.13	_−.63**_	.61**	.20	_−.64**_	20
_J-1_							
3 to 7 days:							
A	.56**	.08	.39	.39	.08	−.35	19
B	.29	−.05	_−.49*_	.01	−.46*	−.40	19
D	.44	−.05	_−.50*_	.67**	.01	−.54*	19
_J-2_							
7 to 10 days:							
A	.35	.14	_−.71**_	_.50*_	.17	−.69	18
B	.53*	.10	_−.57*_	.14	−.60**	−.56*	18
D	.35	−.01	−.41	_.71**_	.10	−.36	18
_J-3_							
10 to 14 days:							
A	_.50*_	.22	−.59*	_.55*_	.31	−.63**	17
B	_.64**_	.22	−.51	.25	−.58*	−.34	17
D	.40	.10	−.41	_.67**_	.12	−.40	17
_J-4_							
14 to 17 days:							
A	_.77**_	.35	−.38	_.59*_	.38	−.37	16
B	_.64**_	.39	−.24	.41	−.17	−.17	16
D	.40	.16	−.25	_.52*_	.11	−.25	16
_J-5_							
17 to 21 days:							
A	_.64*_	.26	−.46	_.67*_	.31	−.47	15
B	_.54*_	.31	−.38	.30	−.28	−.37	15
D	.49	.20	−.17	_.66**_	.21	−.19	15

[1] Correlation coefficients are italicized if significance for a particular combination was found in at least 2 of the 3 locations tested.

[2] Weather variables were not measured before sampling period 1.

*Significant at 5-percent level.

**Significant at 1-percent level.

TABLE 7.—*Correlation coefficients of numbers of adult insects captured in light traps in a sampling period compared with the average relative humidity during this period and during each of the 5 previous sampling periods* [1]

Sampling period, days before insects were trapped, and peanut-storage area	Ultraviolet light			Green light			Number of sampling period observations [2]
	Indian-meal moths	Almond moths	Rice moths	Indian-meal moths	Almond moths	Rice moths	
J							
0 to 3 days:							
A	−0.03	−0.20	0.40	0.04	−0.22	0.37	20
B	−.07	−.25	−.09	.01	−.25	−.09	20
D	−.05	−.31	−.08	−.09	−.37	−.09	20
J-1							
3 to 7 days:							
A	.03	−.19	−.02	.05	−.20	0	19
B	.13	−.24	−.09	.11	−.18	−.06	19
D	−.09	−.39	−.10	−.07	.25	−.11	19
J-2							
7 to 10 days:							
A	.12	−.12	−.53*	.28	0	−.56*	18
B	.04	−.04	−.36	.02	−.05	−.46	18
D	.11	−.39	−.12	.08	−.28	−.09	18
J-3							
10 to 14 days:							
A	.57*	.22	−.39	.32	.31	−.42	17
B	.23	.21	−.37	−.05	.25	−.29	17
D	.20	−.07	−.34	−.02	−.14	−.30	17
J-4							
14 to 17 days:							
A	.30	_.58*_	−.30	.28	_.67**_	−.29	16
B	.13	_.70**_	−.28	.16	_.68**_	0	16
D	.29	.35	−.43	.45	.31	−.40	16
J-5							
17 to 21 days:							
A	−.17	_.56*_	−.37	.02	.54*	−.35	15
B	−.03	_.53*_	.06	−.01	.51	.17	15
D	.14	.25	.02	.11	.36	−.03	15

[1] Correlation coefficients are italicized if significance for a particular combination was found in at least 2 of the 3 locations tested.

[2] Weather variables were not measured before sampling period 1.

*Significant at 5-percent level.

**Significant at 1-percent level.

TABLE 8.—*Correlation coefficients of numbers of adult insects captured in light traps in a sampling period compared with the average vapor-pressure deficit during this period and during each of the 5 previous sampling periods* [1]

Sampling period, days before insects were trapped, and peanut-storage area	Ultraviolet light			Green light			Number of sampling period observations [2]
	Indian-meal moths	Almond moths	Rice moths	Indian-meal moths	Almond moths	Rice moths	
J							
0 to 3 days:							
A	0.63**	0.11	_—0.51*_	0.33	0.10	_—0.49*_	20
B	.20	.12	_—.50*_	.26	.11	_—.46*_	20
D	.24	.14	—.39	.45*	.24	—.40	20
J-1							
3 to 7 days:							
A	.54*	.11	—.38	.36	.12	—.37	19
B	.13	.04	—.38	.16	.04	—.40	19
D	.43	.10	—.27	.52*	.08	—.28	19
J-2							
7 to 10 days:							
A	.28	.19	—.44	.32	.14	—.41	18
B	.50*	.07	—.32	.67**	.12	—.26	18
D	.15	.13	—.24	.44	.09	—.23	18
J-3							
10 to 14 days:							
A	.17	.18	—.41	.40	.20	—.44	17
B	.49*	.15	—.32	_.61**_	.14	—.45	17
D	.17	.21	—.18	_.53*_	.27	—.17	17
J-4							
14 to 17 days:							
A	_.78**_	.04	—.27	_.53*_	.03	—.25	16
B	.70**	—.04	—.11	_.79**_	.03	—.20	16
D	.15	—.15	.04	.16	—.12	—.01	16
J-5							
17 to 21 days:							
A	_.63*_	—.03	—.36	_.78**_	.06	—.38	15
B	_.57*_	.04	—.46	_.66**_	.03	—.44	15
D	.25	—.05	—.12	.46	—.08	—.07	15

[1] Correlation coefficients are italicized if significance for a particular combination was found in at least 2 of the 3 locations tested.

[2] Weather variables were not measured before sampling period 1.

*Significant at 5-percent level.

**Significant at 1-percent level.

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